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A METHOD OF DETERMINING
THE ANOMALIES OF REFRACTION
OF THE
HUMAN EYE.

BY

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A METHOD OF DETERMINING THE ANOMALIES OF REFRACTION IN THE HUMAN EYE.

THE following method for diagnosing the anomalies of refraction, and determining their degrees, depends upon the intervalle focal, or Brennstrecke of Sturm, or the artificial formation thereof, and Stokes' Lens, for a lucid description of both of which I beg to refer to Donders classic work.[1]

Stokes' Lens, as I have usually seen it arranged, is by no means convenient for the patient himself to adjust, and this want of easy adjustment may be the reason of its being so seldom employed, even in those cases to which it has hitherto been considered applicable. The instrument as made by Crétès, of Paris, being more convenient, both for patient and practitioner, I will here mention the modifications which it possesses. The two cylindrical lenses are mounted in a circular box having a handle attached to it, on which handle a button slides, rotating the lenses on each other. The amount of rotation which corresponds to the position of the button—serving, also, as an indicator—having been previously determined, and the effect so given to each of the cylindrical lenses calculated,[1] the number of the equivalent lens is marked on the side of the handle, so that as the indicator is moved along the effect produced can be at once read off; the effect of the combined lenses being, of course, double the amount numbered on the scale :—

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[1] 'On the Anomalies of Refraction and Accommodation of the Eye,' by F. C. Donders, M.D., published for the New Sydenham Society, 1864, pp. 452 and 486.

E.g. When the indicator is moved to 20, the action of the concave cylindrical lens, on a plane of parallel rays coinciding with its axis, is to make it divergent, as if the rays came from a point at 20″ in front of the lens; and a plane of parallel rays coinciding with the axis of the convex cylindrical lens, is made convergent to a point corresponding to the amount of its action, *viz.* 20″.

By having the axes of the lenses when they are at the zero point (o)—*i.e.* when the axes correspond, and the two lenses neutralize each other, so that there is no action, standing at an angle of 45° from the vertical, instead of vertical as usually placed, you can turn either lens upwards or downwards, so that the axis assumes a horizontal or vertical position without necessitating the movement of the entire lens, which you would require should you wish to have a vertical or horizontal action —the actions generally sought—when the usual Stokes is employed.

These two modifications in the arrangement of the lens from that usually seen, are of great assistance both to the oculist and patient, and it is of the instrument as so arranged that I speak.

We have seen above, that any rotation of the lenses on each other gives to each lens an equal action. Not only are the two powers so produced equal, but each power acts perpendicularly to the other, so that the convex cylindrical lens acts as a lens standing at right angles to the concave cylindrical lens of the same strength:—

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[1] For the Formula *vide* Donders, British Association Reports for 1849, &c.

E.g. When the indicator stands at 20, the concave cylindrical lens acts as a concave cylindrical of $\frac{1}{20}$ with its axis horizontal $(-\frac{1}{20}c \longrightarrow)$, and the convex cylindrical lens as a convex cylindrical of $\frac{1}{20}$ with its axis vertical $(\times\frac{1}{20}c\uparrow)$, or *vice versâ*; and the desired position of each lens can be called into action according as you move the indicator upwards or downwards. Moving the indicator downwards, the convex lens acts as a convex-cylindrical lens with its axis vertical, $(+c\uparrow)$, and the concave lens as a concave cylindrical lens with its axis horizontal $(-c \longrightarrow)$; while on moving the indicator upwards the reverse is obtained, the convex cylindrical acting as a convex cylindrical with its axis horizontal $(+c \longrightarrow)$, and the concave cylindrical as a concave cylindrical with its axis vertical $(-c\uparrow)$.

By the above it will be seen that two planes of parallel rays perpendicular to each other, passing through the lenses standing at any desired angle to each other, will be acted upon by them in exactly opposite manners, though of equal degrees. If, now, a pencil of parallel rays strike the lens while the indicator stands at 20 downwards, those rays passing through the horizontal meridian will be converged to a point at 20″ behind the lens, those passing through the vertical meridian being made to diverge as if they came from a point 20″ in front of the lens, the former having been influenced by the convex cylindrical with axis vertical $(+\,c\uparrow)$, and the latter by the concave cylindrical with its axis horizontal $(-\,c\longrightarrow)$, and thus forming a focal interval equal to the action of both lenses. With the indicator standing at 20 upwards exactly the opposite effects would be produced.

I apply the instrument to the diagnosis of the ametropia in the following manner:—

Looking towards a dark screen standing at 20′, through which a small round aperture has been bored, the aperture being turned towards the globe of a lighted lamp, or other clear light, an emmetrop will see a clear round light free from diffusion-images of any kind.[1] In such the pencils of rays passing through the different meridians of the eye come to a point on the percipient layer of the retina, and any lens added to such an eye would, by changing the position of the point of convergence of the rays in relation to the retina, only produce ametropia, and give diffusion-images whose extent would be in proportion to the ametropia produced. Should, however, diffusion-images caused by one of the conditions of ametropia be seen, by rotating the two cylindrical lenses in Stokes' lens on each other before the eye, a rotation will be arrived at where the action of one or other of the lenses will cause the diffusion-images of one meridian to disappear, the rays passing through the said meridian being brought to a point on the retina, supposing always that the ametropia is not greater than the strongest available action of one of the lenses; while the opposite lens will double the ametropia of the other meridian, giving a clear line of light, which, according to its position, and the number to which the indicator requires to be moved along the handle of Stokes to obtain it, gives the condition of refraction present, and its amount in the meridian thus rendered emmetropic.

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[1] This is not strictly true, as perhaps there is no eye which is not slightly ametropic in some way or other, so that diffusion-images are seen to some extent; but for practical purposes we speak of what is usually accepted as emmetropic. In what follows I speak generally, for simplicity's sake, of the two chief meridians only without calculating the usual distance of the lens from K in the ordinary way.

E.g. A patient says the round diffusion-image seen without help of lenses becomes, on moving the button on Stokes' lens downwards at a certain position of the indicator, a vertical line of light; the number at which the indicator stands gives the amount of ametropia of the meridian whose diffusion-image has disappeared. But by this rotation we can not only determine the amount of the ametropia of that meridian, but also the condition of ametropia, whether hypermetropic or myopic, as, should he have obtained a vertical line of light, knowing that the lens acts on being moved downwards as a $+ c \uparrow$, and therefore acting upon the rays passing

> through the horizontal meridian, and as a $- c \longrightarrow$ acting on the rays passing through the vertical meridian, we diagnose hypermetropia, as here the rays, passing through the horizontal meridian, have been alone corrected and brought to a point on the retina, leaving the rays passing through the vertical meridian uncorrected, or rather increased in their ametropia. Should he, on the other hand, say that he obtains a horizontal line, the diagnosis is myopia, and the degree is arrived at in the same way. The hypermetrop, on moving the lens upwards, will now obtain a horizontal line, and the myop a vertical one, and the difference of the two numbers obtained at which the vertical and horizontal lines were seen in either case will give the astigmatism, if any, a slight amount being nearly always present.[1]

I have given a diagrammatic representation of each anomaly of refraction, and how the lens acts on such, to which I beg to refer. (*Vide* Cases I. of H. and M.)

In the diagnosis of the cases of astigmatism, we have (Donders, p. 481) to determine—

"*a*. Its existence.

"*b*. The direction of the principal meridians, those of the maximum and minimum of refraction.

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[1] The diagnosis of all the refractive conditions may also be obtained when the light test is used by the old method of passing a piece of cardboard, or other screen, before part of the pupil of the patient, and asking him at which side the light is abstracted, if at the same side as the screen is passed myopia is present; if at the opposite side, hypermetropia.—*Vide* Verschoors Optometrie.

"*c.* The refractive condition of the eye in each of these meridians.

"*d.* The degree of the astigmatism."

Taking the light as the method, we arrive at the diagnosis of the "existence" of astigmatism by the form of the light, as, if astigmatism be present to any degree, the diffusion-images will not form a circle on the retina, as in simple hypermetropia or myopia; but in proportion to the extent of the deviation from the circular form, so is the amount of the astigmatism greater.[1]

For the determination of the "direction of the principal meridians, those of the maximum and minimum of refraction," the direction of the axis of the longest diffusion-image gives it; but as this cannot be given by the patient with the exactitude required, I have devised the following method:—In the centre of a screen on which a graduated half circle arc is drawn, (the vertical 0°, and going on either side to 90°), an aperture is bored the same as in the screen before mentioned, and a second screen, with a like aperture placed a little distance short of the radius of the graduated circle, is placed over the first screen. Each screen must be so cut out that the aperture of the other is left always uncovered, while by moving the second screen the aperture therein can be brought to stand at any desired angle to the central aperture. These are placed before a light as before. Should the patient say that the light is lengthened in one direction more than another, I revolve the smaller screen, so that the eccentric light moves round the central light at a radius shorter than that of the graduated arc, and ask the patient to say when the two lengthened lights (for, of course, the two apertures, being of the same diameter, will give exactly the same diffusion-images) come into the same line, or form one lengthened line. At the point at which he says this occurs, I read off the arc the degree which lies in a line with the two apertures, and thus obtain the exact meridian of the greatest ametropia.

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[1] This is speaking of astigmatism (diag. 15) simple and compound, but not mixed, as there, as we shall see, the diffusion-image returns more to the circular form according as the different conditions of refraction approach each other in degree.

The next point to be determined is "the refractive condition of the eye in each of these meridians." This is at once done either by successively placing a screen before part of each of the meridians of the eye (*V.* note, p. 4) corresponding to the maximum and minimum curvative, or by the character of the diffusion-images obtained on moving Stokes' lens before the eye, as, should the case be one of hypermetropic astigmatism, simple or mixed (A *h* or A *h m*), movement downwards—the lens being placed parallel to the meridian of greatest ametropia—will only cause a greater diffusion-image in all directions; while, if moved upwards, a line of light will be obtained as before. With compound hypermetropia (H + A *h*) a line is obtained on moving downwards, which you diagnose from a myopic line by the fact that it is a vertical line,—the axis of the lens being vertical—while in myopia it is a horizontal line; and further, from the fact of a round diffusion-image being perceived before the line has been obtained in myopia, while a round diffusion-image is obtained in the hypermetropic case only on the lens being moved upwards. Perhaps the first-mentioned method is the readiest to determine this point, and will probably be preferred.

The "degree of the astigmatism" is determined simply by the amount of movement of the indicator on the Stokes which is required to abolish the diffusion-images in each meridian, the number of the lens corresponding to the position of the indicator being engraved on the handle as before mentioned.

As I have annexed an example of each condition of refraction, and the action of the lens thereon, I need not enter into further details. I may, however, mentiōn that this method is applicable to Snellen's test-lines, which are in such general use, and that different modifications of the light-test may be used according as it is considered most easy to determine when a sharp line is obtained. A small central light, with four others at equal distances therefrom, or three lights, I have found useful. A modification of Scheiner's experiment which I have proposed, consisting of employing five holes, or nine holes, or three on different meridians instead of the two employed by Scheiner, Pakefield, Thomson, and others, is useful in determining the degree in the different meridians with great exactitude, and may be used in some cases with advantage.

I also believe it useful to have a shade with the various diffusion-image shapes usually seen cut out and placed over a lighted lamp near the patient, so that he has no explanation to make as to what he sees, but points at once to the oval or line resembling the one he sees in the distance in form and position, and which gives the practitioner at once a clue as to the ametropia, its amount, and meridian of greatest and least curvature.

To obviate the objection applicable to all optometers hitherto proposed, *viz.* that you do not at the same time with the determination of the condition and degree of refraction present, determine the acuteness of vision, I propose the following methods which at the same time will act as controls,—though the latter is done to a considerable extent by the different diffusion-images said to be obtained on moving the indicator upwards and downwards. The first method will perhaps best be explained by taking an example.

The patient saying he sees an oval light, I obtain the meridian of the maximum refraction according to the method described—say, it is horizontal. He moves the Stokes' lens, placed with its axis horizontal, downwards, and obtains first a round diffusion-image at 60, and a vertical line at 12; I diagnose myopia, maximum refraction horizontal $\frac{1}{12}$ (M. max. $\longrightarrow \frac{1}{12}$), difference of the two meridians (As) $\frac{1}{30}$. He now moves the lens upwards, and obtains a horizontal line at 20; diagnosis myopia, minimum refraction vertical $\frac{1}{20}$ (M. min. $\uparrow \frac{}{20}$). I now place Snellen's types[1] before him at a short distance, 5′—10′, and placing the lens horizontally, ask him to move it until he sees the letters sufficiently well to read some of them—say XX or XL—which he will do at 60 downwards, that is, when the astigmatism has been neutralized, and the case is reduced to one of myopia of $\frac{1}{15}$ ($\frac{1}{12} - \frac{1}{60} = \frac{1}{15}$; $\frac{1}{20} + \frac{1}{60} = \frac{1}{15}$). I then place $-\frac{1}{15}$ before the Stokes, and, should the case be one of anomaly of refraction only, it will be corrected, and the acuteness of vision also determined, though it must be admitted that in very few cases of astigmatism of any extent is a perfect acuteness obtained, owing possibly to the non-correction, or the increase, of the irregular astigmatism by the glasses employed to correct the regular astigmatism. Or the one meridian having been determined, and the other being found to be the same by turning the entire lens on its axis, you have simply to calculate how much the ametropia has been increased in the other meridian, to know which cylindrical lens to set before the eye with the axis at right angles to that of the correcting lens, to get a spherical action and allow him to read. *E. g.* A patient says he gets the vertical line of Snellen's types black and distinct with the indicator at 15, and on turning the axis of the lens in the opposite direction the horizontal line is also black and distinct; by calculating that the ametropia of the other meridian has been increased to $\frac{2}{15} = \frac{1}{7 \cdot 5}$, you place a cylindrical $\frac{1}{7 \cdot 5}$ (convex or concave as required) with its axis at right angles to that of the convex or concave cylindrical in Stokes, which has neutralized the ametropia in the other meridian; and thus make the rays passing through both meridians converge to a point on the retina.

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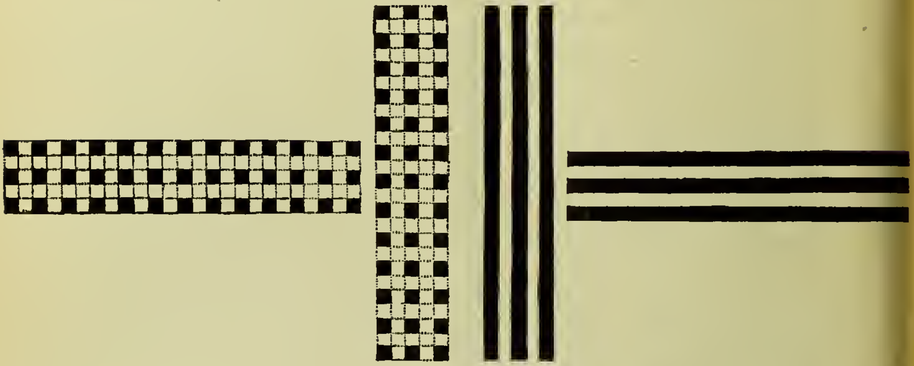
[1] The lines may be used, the position of the indicator, when the lines are all equally well seen, being noted.

The other method is by the use of lines the same as those at present being tried by Dr. Snellen as tests to determine the refraction, only placing them on different meridians,—or lines or points of light, if the light-test is used—so that the patient gives the *number* of lines as the test of his acuteness of vision in each meridian.



I believe that the speed with which the determination of the refraction in the different meridians is made, the simple calculation which allows the practitioner to place the cylindrical or spherical lens, or both required before the patient, and the ability to determine better the refraction in patients with diminished vision, give this method some advantages, which I trust may be of some service.

I propose to apply the same principle to the determination of the refraction ophthalmoscopically, so that the practitioner will have it in his power to determine for himself the refraction of all the different meridians by a much more expeditious method than that now employed. But the method and description of the modified lens I propose to use, will form the subject of a separate paper.

CASES OF HYPERMETROPIA.

Stokes' Lens acts when moved—

Upwards, as a − *c* ↑ and a + *c* →

Downwards, as a − *c* → and a + *c* ↑

(The lens supposed to be held vertically.)

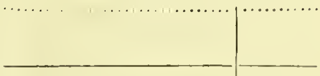
The perpendicular line marks the position of the retina.

The dotted line marks the point of crossing of the rays passing through the vertical meridian.

The black line marks the point of crossing of the rays passing through the horizontal meridian.

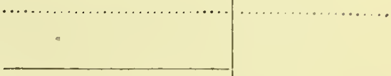
Case I.—*Simple Hypermetropia.*

The lens moved *downwards* acts as − *c* → + *c* ↑



and thus brings the rays which have passed through the horizontal meridian on to the retina, while the rays through the vertical meridian are made still more ametropic, and a bright vertical line is seen. The action is represented thus:—

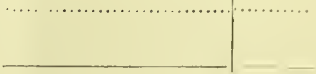
Effect produced .. ..



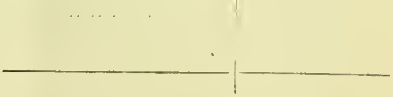
(The patient may now be requested to turn the lens horizontally, and if he gets a sharp horizontal line, this is the amount of the hypermetropia of his vertical meridian also; should he, however, require to move the slide slightly to get a horizontal line (which is nearly always the case), the difference of the two numbers gives the astigmatism.)

The same case, with the lens moved upwards, is shown in the following:—

Lens moved *upwards* acts as a + *c* → − *c* ↑



Effect produced .. ..



The hypermetropia of the vertical meridian is corrected, while the hypermetropia of the horizontal meridian is doubled, giving a horizontal line.

Should the number on the scale be different from the number which was given on moving the lens downwards to obtain the vertical line, the difference gives the astigmatism.

Case II.—*Hypermetropic Astigmatism.* (Ah.)

Emmetropia in the horizontal meridian. (E in horizontal meridian.)

Hypermetropia in the vertical meridian. (H in vertical meridian.)

(Place lens in the direction of the ametropic meridian.)

Lens moved *upwards* acts as a
+ *c* → ………………………………… …………
− *c* ↑ ——————————

The vertical line seen before the action of the lens gives place to a round diffusion circle (which may be noted as a controller) and is gradually replaced by a horizontal line when the lens has fully corrected the astigmatism.

Effect produced .. ..
………………………………… ……
—————————— ————

That it is hypermetropic astigmatism is immediately diagnosed by the fact that moving the lens upwards reduces the line present and gives another. If the lens were moved downwards, the circles of diffusion would be increased in all directions.

Case III.—*Compound Hypermetropic Astigmatism.* (H + Ah.)

Hypermetropia in horizontal meridian, with greater hypermetropia in vertical meridian.

(Place the lens in the direction of the greatest ametropic meridian.)

Lens moved *downwards* acts as a $\left\{\begin{array}{l} -\ c \rightarrow \\ +\ c \uparrow \end{array}\right.$

Effect produced, giving the hypermetropia in the horizontal meridian ..

Lens moved *upwards* acts as a $\left\{\begin{array}{l} +\ c \rightarrow \\ -\ c \uparrow \end{array}\right.$

Effect produced at the number on lens giving half the difference of each, the oval (vertical) having given place to a round diffusion circle. This number may be used as a controller of the power given as the producer of the horizontal line .. ..

Effect produced at the full neutralization of the hypermetropia of the vertical meridian .. ..

Case IV.—*Mixed Astigmatism.* (Ahm.)

Hypermetropia greater in the horizontal meridian than the myopia in the vertical meridian.

(Place the lens parallel to the greatest ametropic meridian.)

Lens moved *upwards* acts as a $\left\{\begin{array}{l} -\ c \rightarrow \\ +\ c \uparrow \end{array}\right.$

(The lens here is parallel to the *horizontal meridian,* and acts as shown.)

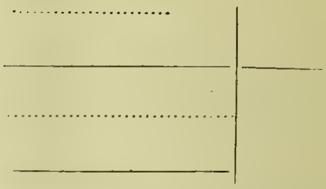
Effect when the myopia is neutralized .. .. ..

Effect when the hypermetropia is neutralized

Case V.—*Mixed Astigmatism,* with the Hypermetropia and Myopia equal in amount.

Lens moved *downwards* as a .. .. $\left\{\begin{array}{l} -\,c \rightarrow \\ +\,c \uparrow \end{array}\right.$

Effect produced .. .. {



CASES OF MYOPIA. (M.)

Stokes' Lens acts when moved—

Upwards, as a − *c* ↑ and a + *c* →
Downwards, as a − *c* → and a + *c* ↑

(The lens supposed to be held vertically; when held horizontally acts in the reverse manner.)

The perpendicular line marks the position of the retina.

The dotted line marks the point of crossing of the rays passing through the vertical meridian.

The black line marks the point of crossing of the rays passing through the horizontal meridian.

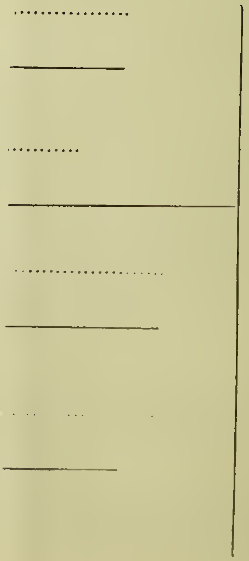
Case I.—*Myopia.*

Lens moved *upwards* acts as a $\left\{\begin{array}{l} +\,c \rightarrow \\ -\,c \uparrow \end{array}\right.$

The round diffusion circle gives place to a vertical line, the myopia of the horizontal meridian having been neutralized }

Lens moved *downwards* acts as a $\left\{\begin{array}{l} -\,c \rightarrow \\ +\,c \uparrow \end{array}\right.$

Effect produced — the round circle being replaced by a horizontal line, the myopia of the vertical meridian being neutralized .. .. }



Case II.—*Myopic Astigmatism.* (Am.)

Emmetropia in horizontal meridian.
Myopia in vertical meridian.
(Place the lens parallel to the ametropic meridian.)

Lens moved *downwards* acts as a
$-c \rightarrow$ ……………………
$+c \uparrow$ ____________

Effect produced—the vertical line being replaced by a horizontal; the myopia of the vertical meridian being corrected, while the emmetropia of the horizontal meridian has been replaced by a myopia equal to the myopia corrected in the vertical meridian .. ..
……………………
____

Case III.—*Compound Myopic Astigmatism.* (M + Am.)

Myopia in horizontal meridian exceeded by the
Myopia in vertical meridian.
(Place the lens parallel to the most ametropic meridian.)

Lens moved *upwards* acts as a
$+c \rightarrow$ ……………………
$-c \uparrow$ ____________

Effect, showing the amount of the least myopic meridian (horizontal) .. ..
……………………
____

Lens moved *downwards* acts as a
$-c \rightarrow$ ……………………
$+c \uparrow$ ____________

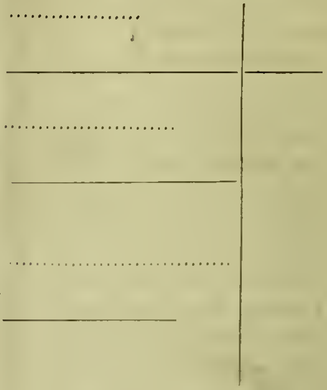
Effect when the myopia of each meridian equal, giving a round diffusion circle in place of an oval
……………………
____

Effect when the greatest myopia corrected (vertical meridian). A horizontal line is seen .. ..
……………………
____

Case IV.—*Mixed Astigmatism.* (Amh.)

Myopia in vertical meridian greater than the Hypermetropia in the horizontal meridian.

(Place the lens parallel to the meridian of greatest ametropia.)



Lens moved *downwards* acts as a $\begin{cases} -\ c \rightarrow \\ +\ c \uparrow \end{cases}$

Effect produced when the hypermetropia is corrected .. ..

Effect produced when the myopia is neutralized. A line seen in opposite direction to the greatest ametropic meridian ..

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Utrecht, *Feb.* 12, 1873.